HOW THE INPUT SHAPES THE ACQUISITION OF INFLECTIONAL MORPHOLOGY:
COMPUTATIONAL MODELLING ACROSS THREE HIGHLY INFLECTED LANGUAGES
Felix Engelmann (University of Manchester), Sonia Granlund (University of Liverpool), Joanna
Kolak (University of Manchester), Virve Vihman (University of Tartu), Ben Ambridge
(University of Liverpool), Julian Pine (University of Liverpool), Anna Theakston (University of
Manchester) & Elena Lieven (University of Manchester)
felix.engelmann@manchester.ac.uk

In order to account for children’s error patterns in the acquisition of complex inflection
paradigms, usage-based (e.g., Bybee, 1995, Lang and Cogn Proc, 10) and even some tradi-
tionally rule-based accounts of morphology acquisition (e.g., Pinker & Ullman, 2002, Trends
in Cogn Sci, 6:11) incorporate input-based learning mechanisms, such as rote-storage and
phonological analogy. According to usage-based accounts, a learner stores highly frequent
words as complete forms in memory and produces low frequent inflections by analogy with
phonologically similar forms. Artificial neural networks have famously been used to argue
against the need for symbolic rules because of their incremental learning with graded sens-
sitivity to input similarities, while applying a single, integrated mechanism to learn regular and
irregular forms (see McClelland & Patterson, 2002, Trends in Cogn Sci, 6:11). But to what
extent can children’s acquisition of complex morphology be explained by a similar mechan-
ism? The majority of previous experimental and computational investigations has focused on
simple systems like English or investigated only a small part of a paradigm. We conducted a
large-scale investigation of the acquisition of the noun and verb inflection paradigms of three
morphologically rich languages by combining experiments and neural network modelling.

Method We carried out elicited-production studies with children between the ages of
three and five on singular noun case marking in Polish, Finnish and Estonian, and present-
tense verb person/number marking in Polish and Finnish. The results were compared with
simulations with three-layer feed-forward networks that were trained on natural, child-directed
speech data. The input to the models consisted of phonemes representing nominative noun
forms (noun models) or verb stems (verb models) and a code for the target case or per-
son/number context, respectively. The models were trained to output the correct phoneme
representation of the target form. Inputs were presented probabilistically according to their
token frequencies in child-directed speech corpora.

Results All models acquired mastery of the system after maximally three million train-
ing trials (presenting one form per trial) and could generalise (i.e., produce the correct target
for untrained items) to 78–88% (except PL nouns with 60%) of the test items used in the ex-
periments. The key phenomena predicted by usage-based theories were observed in both the
experiments and the simulations: effects of token frequency and phonological neighbourhood
density (inflectional class size) of the target form, and a general error pattern that involved the
replacement of low-frequency targets by higher-frequency forms of the same lemma, or forms
with the correct case or person/number, but with a suffix from an inappropriate inflection class.
The models furthermore showed an interaction that is predicted theoretically but wasn’t found
experimentally, namely that the effect of phonological neighbourhood was smaller for items
of higher token frequency, suggesting that analogy is used mainly for low frequent forms. Fi-
nally, hierarchical clustering of the models’ internal representations revealed that lemmas were
grouped on the basis of phonological similarities that included items from different inflection
classes. Errors could therefore be better predicted when defining phonological neighbourhood
with a computational measure of similarity instead of a class-based one.

Our findings demonstrate that acquisition of highly complex systems of inflectional mor-
phology can be accounted for by rote storage and phonological analogy, as opposed to formal
symbolic rules. The fact that this process can be modelled theoretically by a simple feed-
forward network speaks in favour of a single, incremental and domain-independent learning
mechanism that operates on graded phonological similarities in the input.